Special Events Imager

Executive Summary

Mission Statement:
Acquire 300m resolution multispectral visible to near infrared (380 - 1000nm) observations from geostationary orbit in order to detect, monitor, quantify, and predict short-term changes for earth science research and application purposes.

SCIENCE

Scientific or Applications Rationale. The Special Events Imager (SEI) is a multi-purpose mission with complementary natural hazard applications and science goals. The SEI concept addresses three areas of concern: 1) responses of terrestrial and marine ecosystems to climate change, and resource sustainability, 2) natural hazards (floods, volcanoes, toxic blooms), and 3) a joint mission with NOAA to transition new technologies from NASA to operational use. The mission will be used to evaluate the utility of high resolution, frequent images by NOAA for inclusion within the operational requirements for Geostationary Operational Environmental Satellite (GOES). This mission is a clear example of the approach recommended by the Committee on Global Change Research of the National Research Council's Board of Sustainable Development, in their report on Research Pathways for the Next Decade for obtaining long term earth observations.

Polar orbiting platforms will carry several visible – near infrared sensors over the next decade. These include the Moderate Resolution Imaging Spectrometer (MODIS) and the Visible/Infrared Imager Radiometer Suite (VIIRS), capable of furnishing highly accurate radiances with high spectral and one kilometer resolution at a global revisit period of approximately two days. The Department of Defense is also preparing a high spatial resolution mission, the Navy Earth Map Observer (NEMO), which also has a several day revisit rate for coastal zone coverage at temperate/low latitudes. These rates of coverage, which are reduced further in the presence of clouds, are sufficient for observing the intrinsic variability of phenomenon on large spatial (basin to global) and temporal (seasonal to decade) scales. Two day coverage, however, is inadequate to address hourly to daily scales which characterize important short-term events in the oceanic, atmospheric, and terrestrial environments. For example, in the coastal ocean, these phenomena include, but are not limited to, tidal mixing, storm surges, and the diurnal variation in phytoplankton abundance and productivity. Similarly, while the 1-km pixels of the polar orbiters are sufficient to spatially resolve various large scale events, such as shelf fronts, they are too coarse for optimal modeling studies and for investigation of tidal fronts and near-shore processes. Furthermore, the current sun-synchronous polar orbiter observations along the coasts are aliased with the tidal frequency. High frequency observations are required to remove the effects of tidal aliasing and to validate tidal mixing terms in coastal ecosystem models. The present GOES observations are too coarse in spatial, radiometric, and spectral resolution to fully meet these needs.

We propose to acquire visible to near infrared (380 - 1000 nm) observations as frequently as every ten minutes from a geostationary platform, on a regional level. Geostationary platforms permit essentially continuous observations that will allow highly dynamic processes, both biotic and abiotic, to be temporally resolved and investigated. Their observations will strengthen our ability to appraise existing conditions and predict short-term changes, and will benefit state and federal agency environmental stewardship and assessment missions and assist their role in hazard detection and monitoring. The geostationary data, combined with the higher spectral resolution data from polar orbiters, will offer for the first time a suite of remote ocean color measurements spanning time scales over at least two orders of magnitude (hours to days). This will permit the interaction between time scales to be characterized and will enable the effect of tidal and sub-daily frequency events in sun-synchronous polar orbiter observations to be assessed and possibly removed. In addition, the high frequency revisit can increase the cloud-free area in a region of broken clouds through cloud filtering and compositing of multiple images.

Towards this end, we propose a joint mission between NASA and NOAA to demonstrate observations of coastal marine and terrestrial ecosystems at required high temporal frequencies using the SEI. SEI is a small, visible area array imager to be mounted on GOES-N or -O. Using a pointable telescope, SEI will be capable of repeating (within minutes) coverage of 300 x 300 kilometer regions located anywhere within the GOES full disk view. This mission is focused on detecting, monitoring, quantifying, and predicting short-marine and other hazards, and the study of short term processes required to understand and predict the response of marine ecosystem dynamics to long-term climatic change. In addition, the mission will supply useful observations of ephemeral events in the terrestrial and atmospheric components of the Earth Science Enterprise, such as floods, volcanic ash plumes, and storms.

The mission represents a joint effort in the development, implementation, testing, and evaluation of an ocean color capability on geostationary platforms. NOAA's lead role in this mission includes: Phase A and Phase B, launch and operation on GOES-N, data acquisition, and near-real time distribution. NASA's role in this mission includes: sensor procurement, evaluation and characterization, operation algorithms, sensor integration, vicarious calibration and initialization, adaptation of algorithms, and science applications including archive. The two agencies will jointly maintain and staff a Mission Office, and share support for the Marine Optical Buoy Site (MOBY) buoy validation program developed by NOAA personnel for Sea-Viewing Wide Field-of-View Sensor (SeaWiFS) and MODIS. If the mission is successful, NOAA would be in a position to include such capability within the operational requirements for its future geostationary satellites.

Figure 1. Chesapeake Bay from SeaWiFS at 1.13 kilometer resolution

Measurement Approach and Specific Objectives. NOAA/NESDIS has begun initial design and implementation of the SEI with MIT Lincoln Laboratory. The mission concept includes 10-12 visible to near-infrared bands, 300 meter instantaneous field of view, with a signal to noise ratio equivalent to SeaWiFS (ca 500) at 900 meter scales, and 12 bit quantization. The band positions and widths will be guided by ocean color needs, as well as terrestrial and atmospheric applications. The SNR is achieved by temporally integrating and averaging of pixel observations. The integration period is variable to enable imaging of bright terrestrial and atmospheric targets as well as dark ocean features. The field of view is directed using a gimballed telescope. Use of the existing GOES-N/-O medium-rate data link limits transmission rate to about 1 full resolution band per minute (100 kbs or up to 1400 images/day with compression). Pointing of the telescope can thus take up to 1 minute and therefore minimize disturbance to the GOES platform.

These geostationary data would address topics that include, but are not limited to

- Quantifying the response of phytoplankton to short-term physical events, such as passage of storms and tidal mixing;
- Monitoring biotic and abiotic material in transient features, such as tidal fronts;
- Detecting, monitoring, and tracking natural hazards, such as oil spills, noxious algal blooms, fires, and volcanic ash clouds;
- Initializing and validating coupled biological-physical ecosystem models of the coastal ocean and land;
- Assessing the effect of tidal aliasing and sub-pixel variability on global estimates from polar orbiting observations; and

- Improving the estimates of hurricane intensification and landfall predictions.

Work will have to be performed in the following areas to fully utilize these data:

- Adaptation of existing algorithms and development of new algorithms to derive geophysical properties;
- Development and implementation of feature detection and tracking algorithms; and
- Development and implementation of appropriate atmospheric correction techniques.

Implementation. Lincoln Laboratory (LL) performed the Phase-A study to develop the SEI instrument for the GOES-N or GOES-O spacecraft. The SEI instrument, however, has few system requirements and flexible spacecraft interfaces and can be flown on a variety of Geostationary Earth Orbit (GEO) spacecraft – either government or commercial. If another GEO spacecraft is required, however, a modular 3-axis stabilization system would be added to the SEI instrument. Both the sensor and the stabilization system are based upon heritage, low-risk, high reliability designs with few components that are not readily available or easy to fabricate. The SEI Phase-B study could select the GEO spacecraft and perform the preliminary instrument design should NASA decide not to include the instrument on GOES.

Images with a field of view of 300 km x 300 km and possessing up to 12 visible and near IR bands will be downlinked to ground at a rate of 1 band per minute. The number of bands in each image are selectable and therefore the downlink time of an image set can range from 1 to 12 minutes. These downlink times are based on the GOES spacecraft; alternate geosynchronous spacecraft may enable faster downlink times.

Top level SEI design features are:

Sensor:

- Single optical path
- Simple filter wheel
- Commercially available CCD array
  - FTT1010 1024 x 1024 frame transfer CCD
  - Pixel size of 12µm for moderate focal length
  - 200 x over-saturation anti-blooming technology
  - Noise performance (~13e-)
  - Low dark current (~20 pA/cm at 25 C)
  - High Full-well capacity (~300,000 e-)
  - Baffles for stray light control
- Calibration from Earth targets, polar orbiter sensors, and lunar observations

Electronics Module:

- Common electronics with Honeywell ESN MCM microcomputer
- MIL-STD1553 or RS-422 spacecraft interface
- Heritage processing software for data processing and control

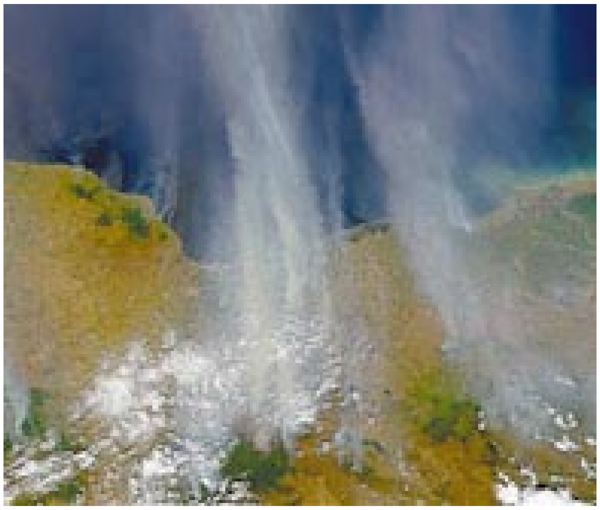

Figure 2. Mexico Fires from SeaWiFS Project

Figure 3. Florida Hurricane from SeaWiFS Project

Science Team. The SEI science team, led by NASA's Dr. Wayne Esaias and NOAA's Dr. Christopher Brown, include recognized leaders in the fields of ocean color, coastal monitoring, data processing, algorithm development, atmospheric chemistry, and vegetation monitoring. Members of the SEI team have established much of the current work in these areas and each team member is committed to furthering the knowledge base and maximizing the scientific and operational basis of the SEI mission. The team will also respond to a joint announcement of opportunity to select science investigations.

TECHNICAL

The SEI mission is a flexible, low-risk, low cost heritage based concept that can be considered as an adjunct for a variety of missions. The SEI Phase-B study will perform the preliminary instrument design and if necessary, evaluate alternate GEO spacecraft.

Mission Design and Spacecraft. The initial design of SEI assumes its integration onto the GOES spacecraft. This joint mission plan is directed toward a GOES implementation. The GOES option is our first choice. It requires the simplest flight interfaces, no stabilization system, and can use existing ground systems (Figure 4a.).

Due to its flexible instrument interfaces, however, SEI is a mission of opportunity that may be supported by other GEO options. (See Figure 4b.). The TDRS option is our second choice because it requires simple interfaces, can employ an existing ground system, but requires a 3-axis stabilization system. The commercial spacecraft is our third and last option. It requires a more complex spacecraft interface, a stabilization system, and a unique ground system. Instrument design can begin before a spacecraft is selected, but a firm decision must be made before instrument PDR, otherwise development cost and schedule will increase. An alternate flight could also alter the partnership arrangement with NOAA considerably, or obviate it completely.

Payload Integration. Each of the GEO spacecraft will have different constraints for footprint, location, electrical and thermal interfaces. Modular design, standard interfaces, independent control, and early bus selection provide confidence in spacecraft compatibility. MIT/LL has a long history of developing instrument and S/C integration, and have a clear understanding of system development.

Manufacturing, Integration and Test. The instrument will be built, integrated, and tested at MIT in their Lincoln Laboratory facility. Processes conducted at MIT/LL for space qualified instruments are machining, clean room fabrication and assembly, environmental testing, and radiometric calibration all conducted in an industry standard environment.

Ground and Data Systems. Both the NOAA/NESDIS Satellite Operations Control Center (SOCC) and the Data Acquisition Center (DAC) can operate the instrument and accept data from any of the spacecraft options. The 24-hour center will produce Level-1A and Level-2 data products. The GSFC SEI Data Processing Center is co-located with the Sea-WiFS Data Processing Center and will ingest the data to provide quality control, data validation/calibration, generate HDF-EOS data products, and archive the data at the GSFC DAAC. The SEI Data Processing Center will also be responsible for the development and integration of new algorithms and software. This software will be provided to the NOAA Data Acquisition Center and other SEI data users.

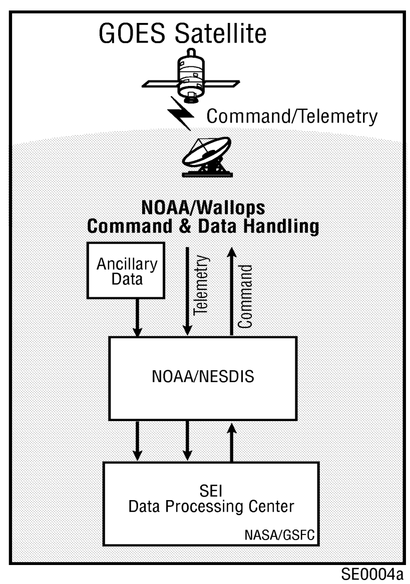

Figure 4a. Space/Ground Data Flow for GOES

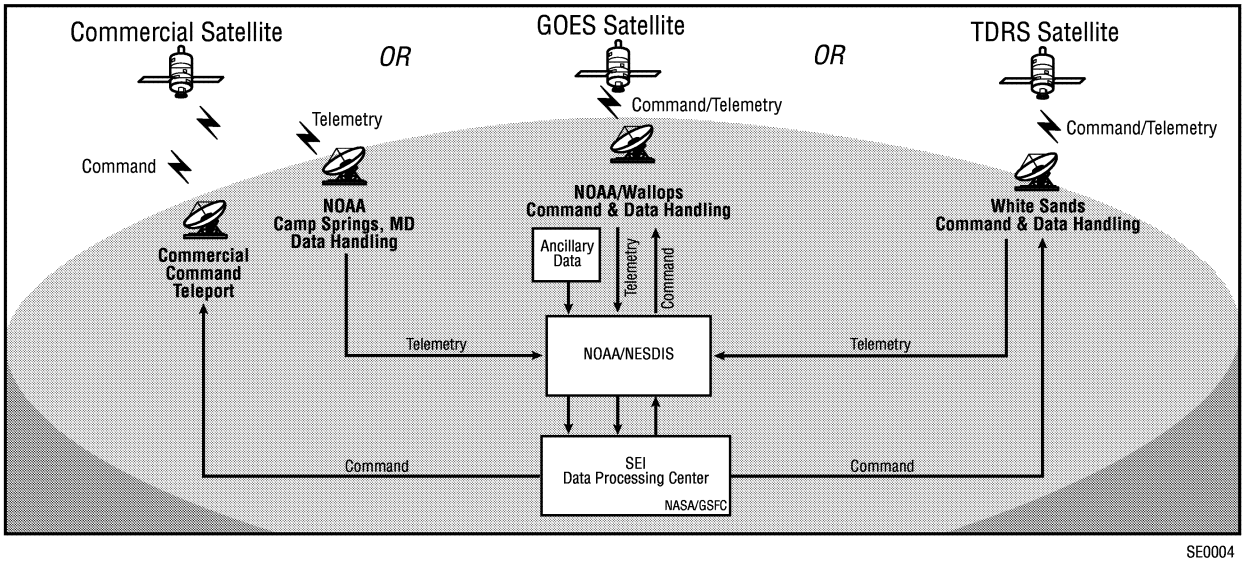

Figure 4b. Space/Ground Data Flow for Three Spacecraft Options

The NOAA OSDPD will perform operational near real time processing and distribute operational products to its CoastWatch nodes for use by local management agencies. State and local government agencies can retrieve their local data over the Internet.

Mission Operations. The SEI mission operations are routine, low risk, and based on existing systems, procedures, and personnel. A joint NOAA, NASA, and University Mission Operations Center (MOC) will process and prioritize pointing and special imaging requests. The MOC will then generate the SEI command schedules and send them to the NOAA SOCC for upload to the spacecraft.

The GSFC SEI/SeaWiFS Data Processing Center will ensure integrity of the science data set and will work with the Science Team and NOAA to validate the data prior to archival.

The SEI instrument will be calibrated by command every month unless something in the data warrants a change to the calibration schedule. The instrument is designed to receive daily pointing schedules, but will default to a set of standard targets if a command schedule is not available. The SEI instrument can also receive software uploads to modify the instruments control system.

Phase B Activities. Phase B, the first 4 months of the program, is focused on establishing the management structure, conducting several studies to mitigate technical risks, selecting the spacecraft, establishing instrument specifications, and completing the design of the instrument and science algorithms.

OPPORTUNITY

Educational and Public Outreach. The SEI mission will return scientific data of interest to both the general public and the research community. A well-balanced set of educational and social programs, including a joint NOAA / NASA exhibit and several world-wide web sites, will educate the public about natural disasters and how the SEI data stream will help mitigate those disasters. The CoastWatch System, already developed by NOAA, will also serve these functions with SEI observations.

The SEI educational outreach program provides support for GSFC's ongoing Teacher Education Center for grades K through 12. In addition, the SEI project will work with Howard University, a historically black college, to educate students on remote sensing and data processing to identify natural disasters. Additionally, the SEI project and Lincoln Laboratory will work with MIT undergraduate and graduate students to develop flight-qualified hardware and software.

Small Disadvantaged Businesses, Women-Owned Small Businesses, Historically Black Colleges and Universities, and Other Minority Educational Institutions. The entire SEI Team is committed to providing subcontracting opportunities for small disadvantaged business, women-owned small business, historically black colleges and universities, and other minority educational institutions. Each member of the SEI team has agreed to a 5% goal for this category of subcontracts.